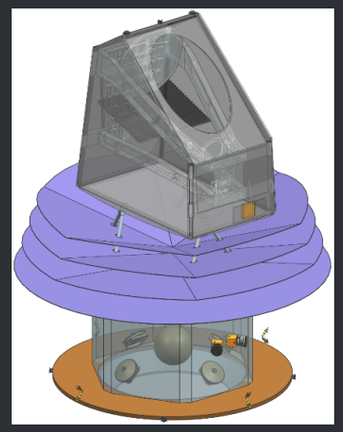


Cosmic Dawn Intensity Mapper
CDIM

Tzu-Ching Chang
(Jet Propulsion Laboratory,
California Institute of Technology)

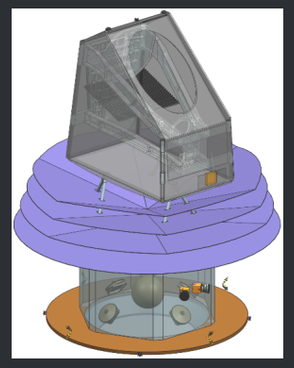
for the

CDIM Science Team

and

CDIM Design Team

Government sponsorship acknowledged



Cosmic Dawn Intensity Mapper (CDIM)

Asantha Cooray, UC Irvine (PI)

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Stephen Unwin, JPL (Study Manager)

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Michael Zemcov, RIT

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Andrew Coffey, JPL (System engineering)

Nasrat Raouf, JPL (LVF filters)

Talso Chui, JPL (Thermal)

James McGuire, JPL (Optics)

Sarah Lipscy, Ball (Bus)

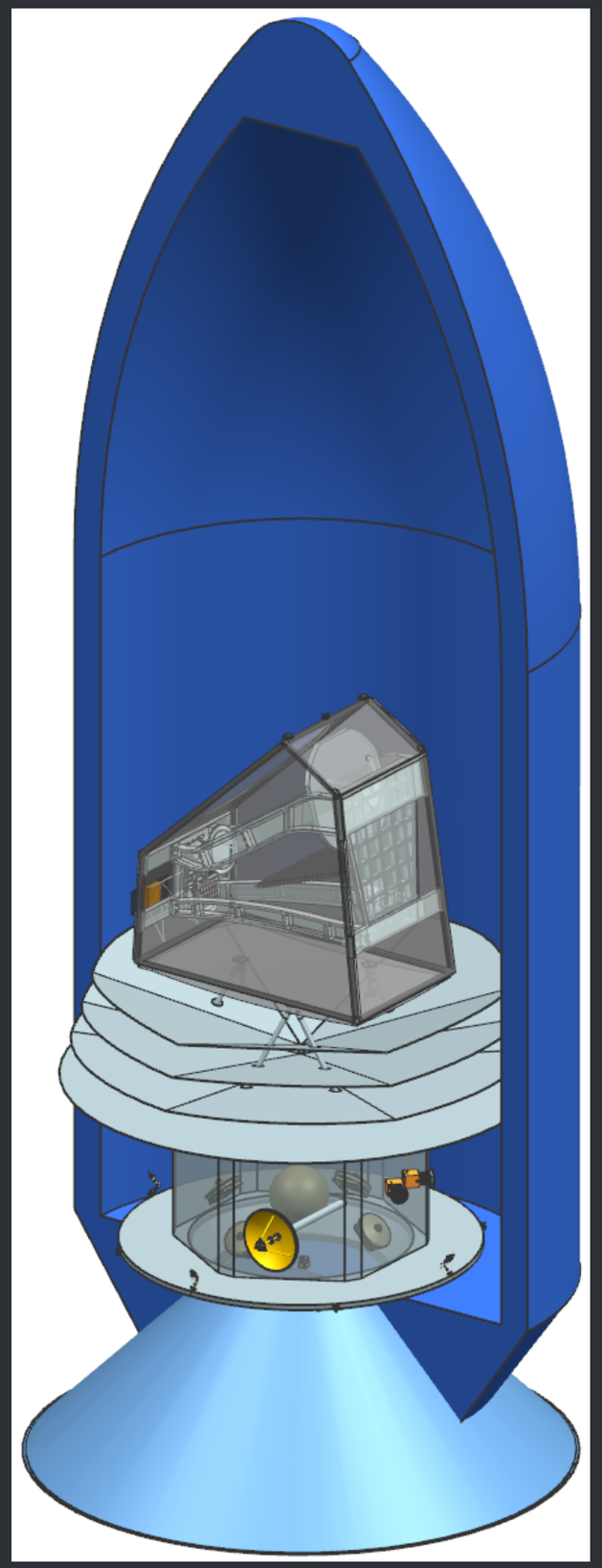
CDIM in a (Falcon-9) Nutshell

NASA Probe class mission concept for the 2020 Decadal review.

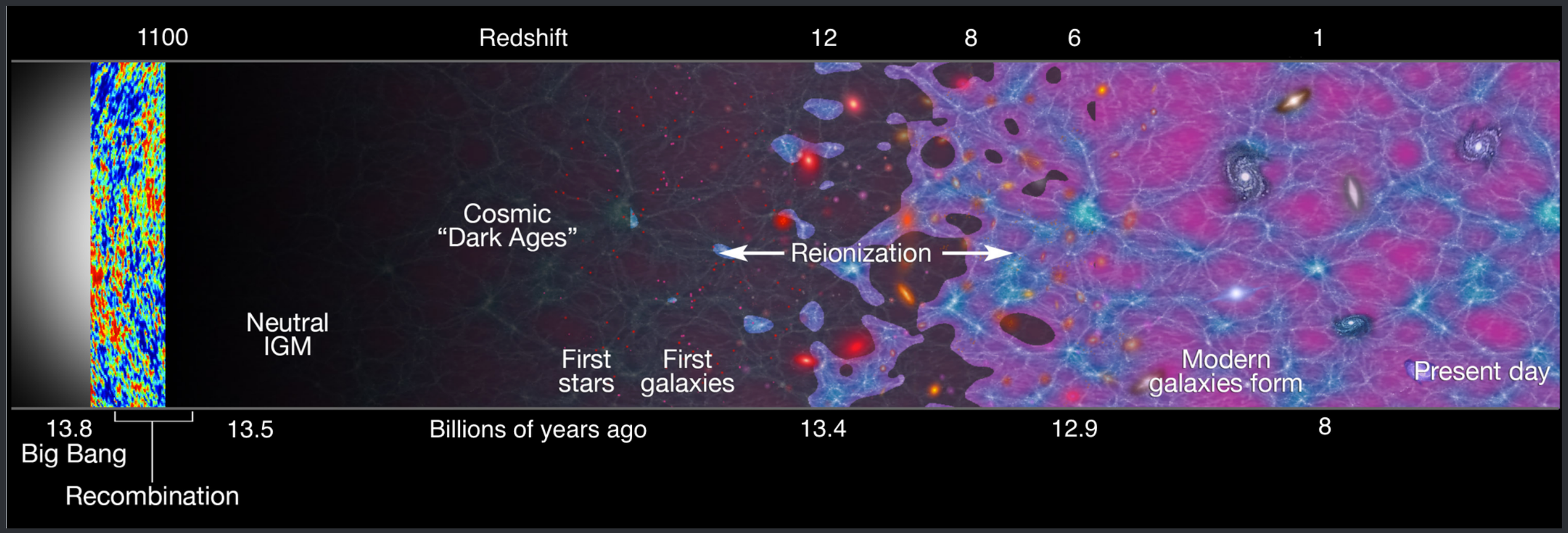
- 0.75 μm – 7.5 μm spectro-imaging in 860 narrow bands at R=300
- 0.8 m effective aperture
- 7.7 sq. degree focal plane
- Diffraction limited at 7.5 μm, 2” PSF
- Three-tired survey in 4 years
- Costed at JPL under 1$B (incl. 30% margin)

Cosmic Dawn and Reionization Sciences

- First Galaxies: tracing Hα to z=10
- First Blackholes: finding AGNs at z=8
- Reionization Tomography: Lyα, Hα intensity mapping, and cross-correlation with 21cm EoR maps

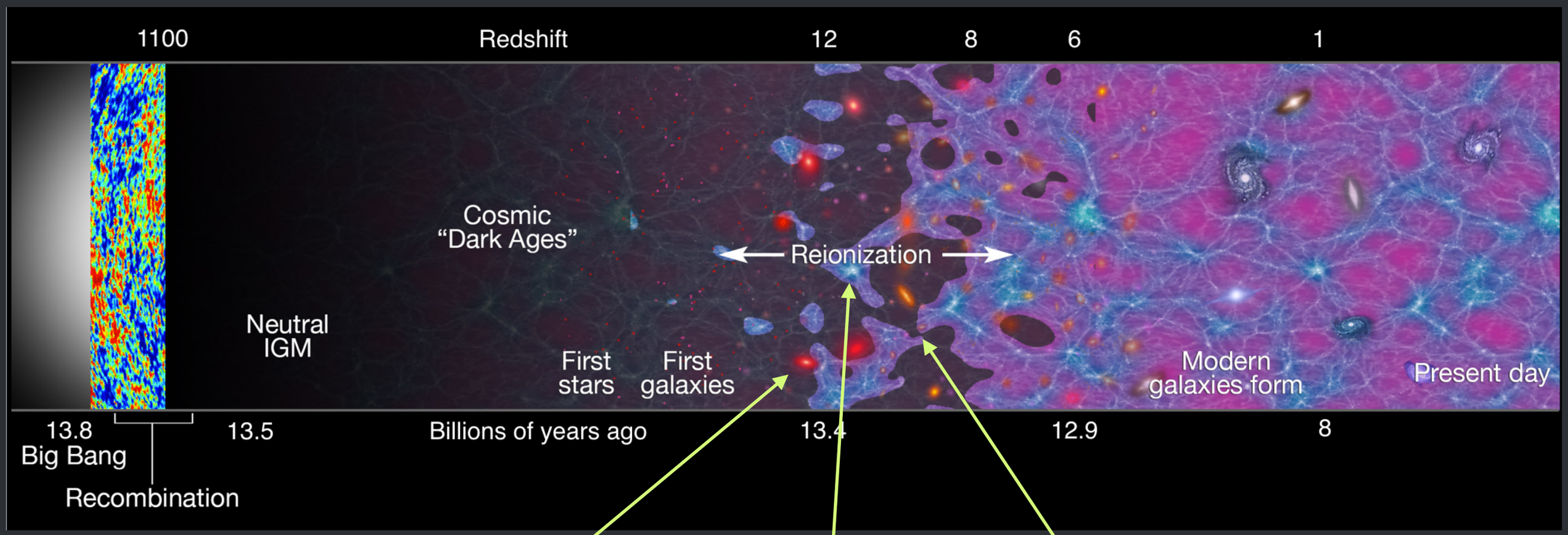


Cosmic Dawn and Reionization



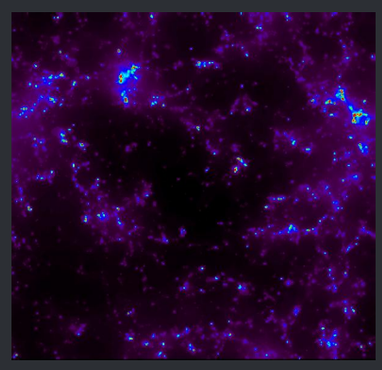
NASA

Cosmic Dawn and Reionization



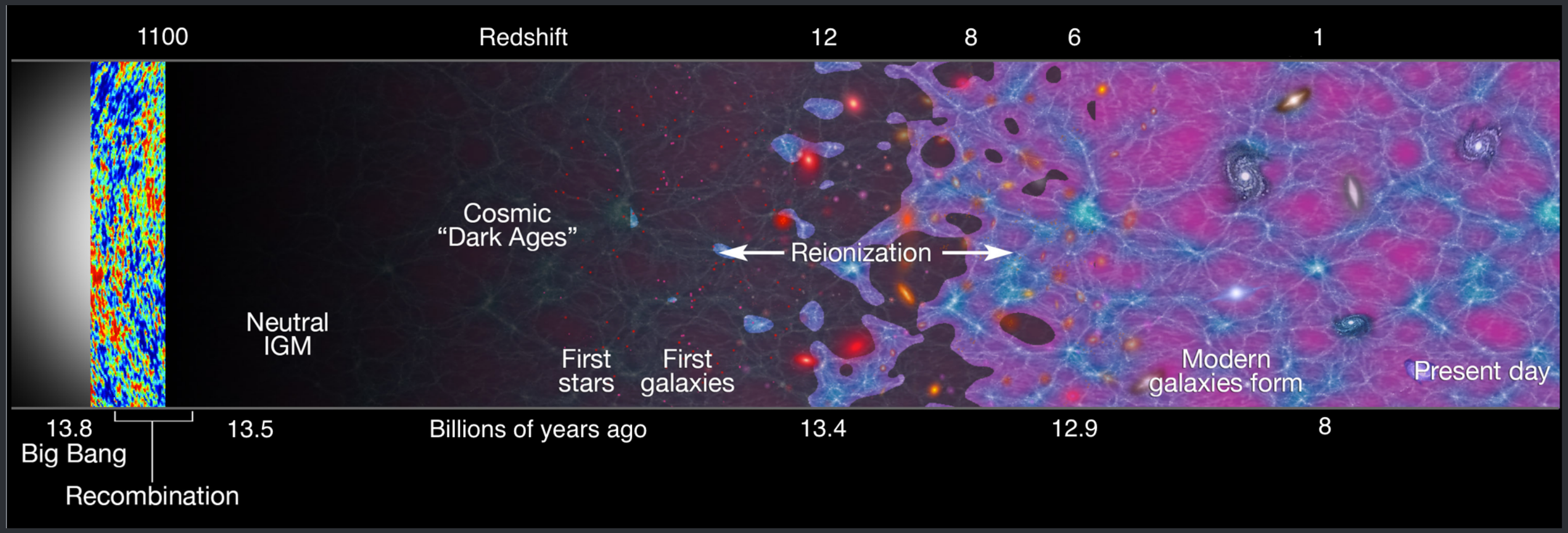
Galaxies

AGN



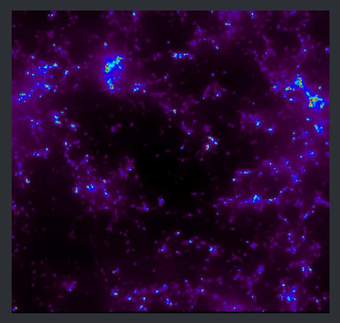
IGM

CDIM Holistic View of Cosmic Dawn and Reionization



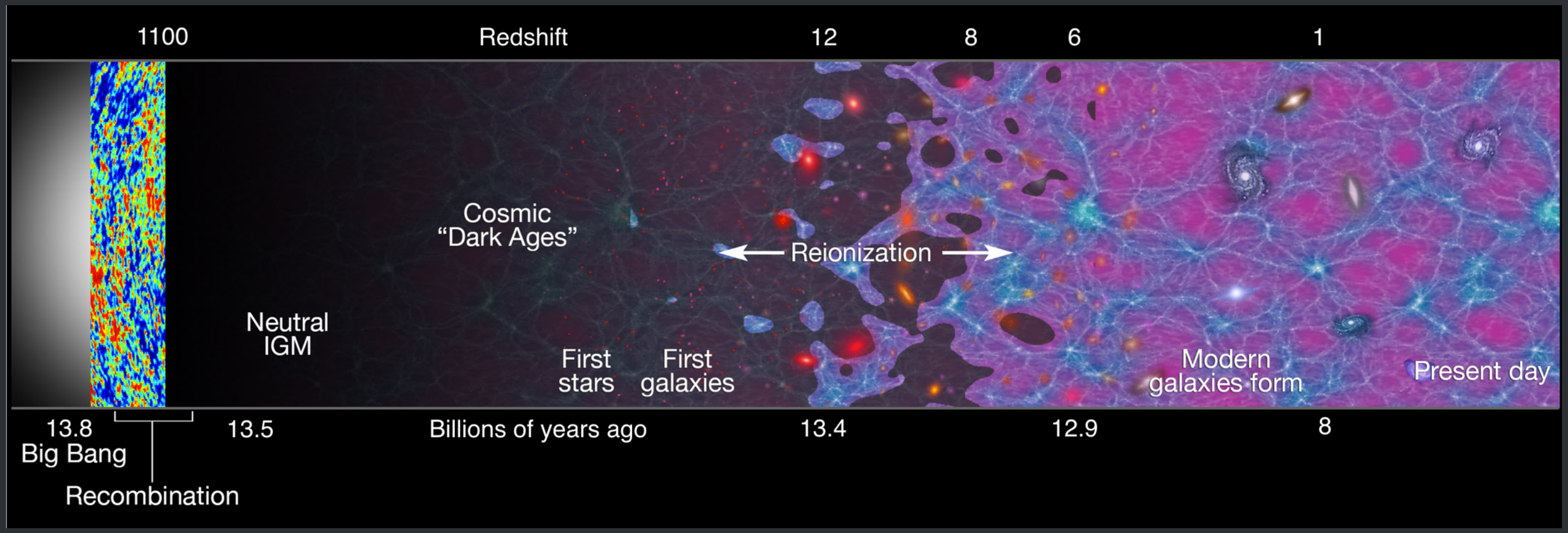
Galaxies: Measuring Hα up to z ~10

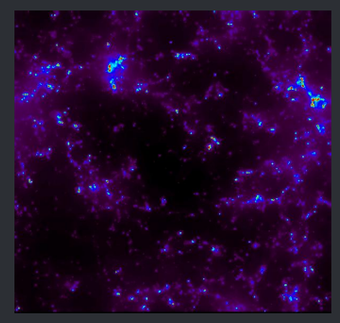
AGNs: Finding blackholes up to z~8



IGM Tomography: reionization topology and history

CDIM Holistic View of Cosmic Dawn and Reionization



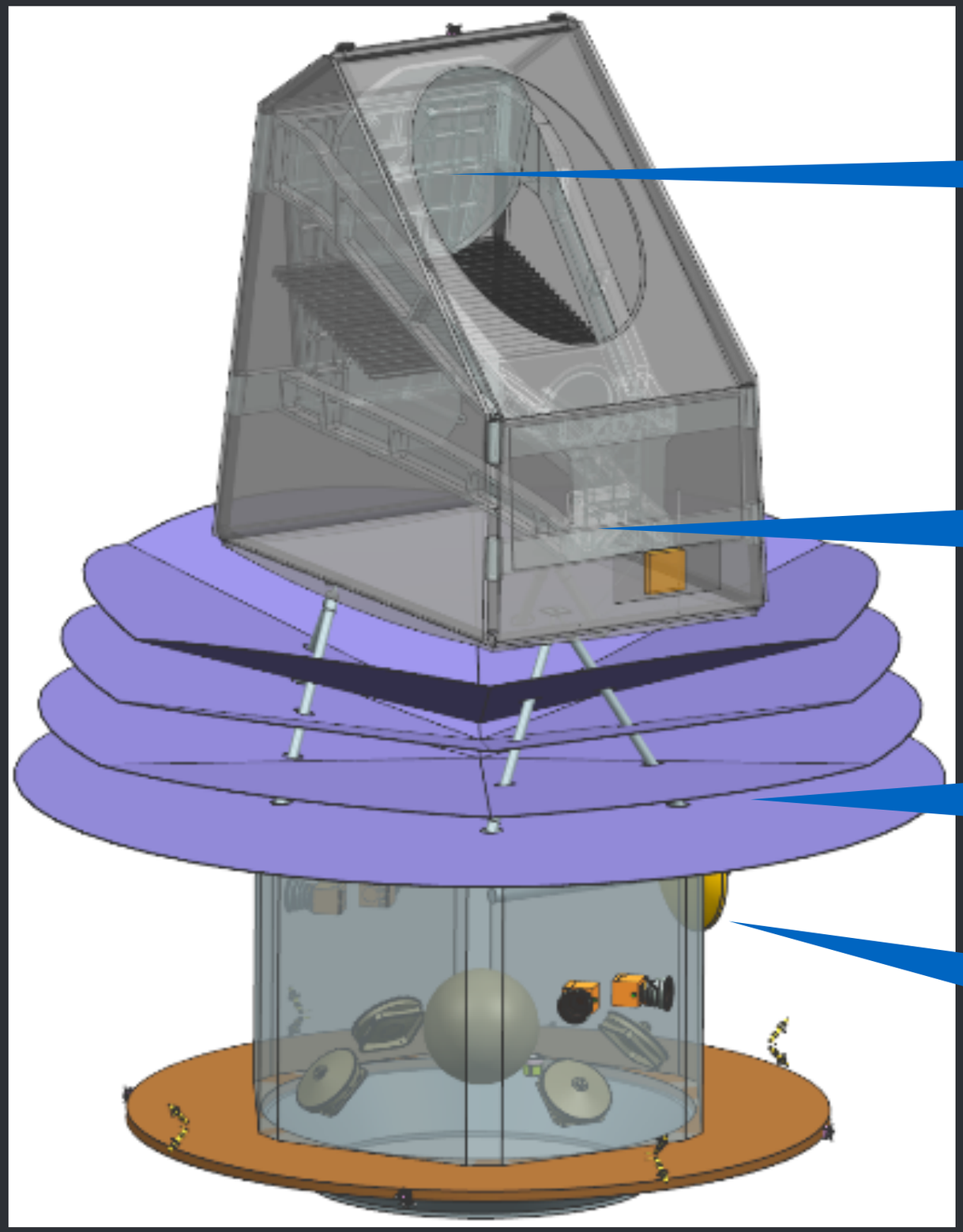


Galaxies:
Measuring Hα up to z ~10
Wavelength 0.75-7.5 microns
R>=300 to separate [NII] &
Line flux sensitivity

AGNs:
Finding
blackholes up to z~8
Large survey area &
point source sensitivity

IGM Tomography:
Reionization topology and
history
Large field of view &
Surface brightness sensitivity

CDIM Design



Three-mirror all-reflective design with 0.8m clear aperture

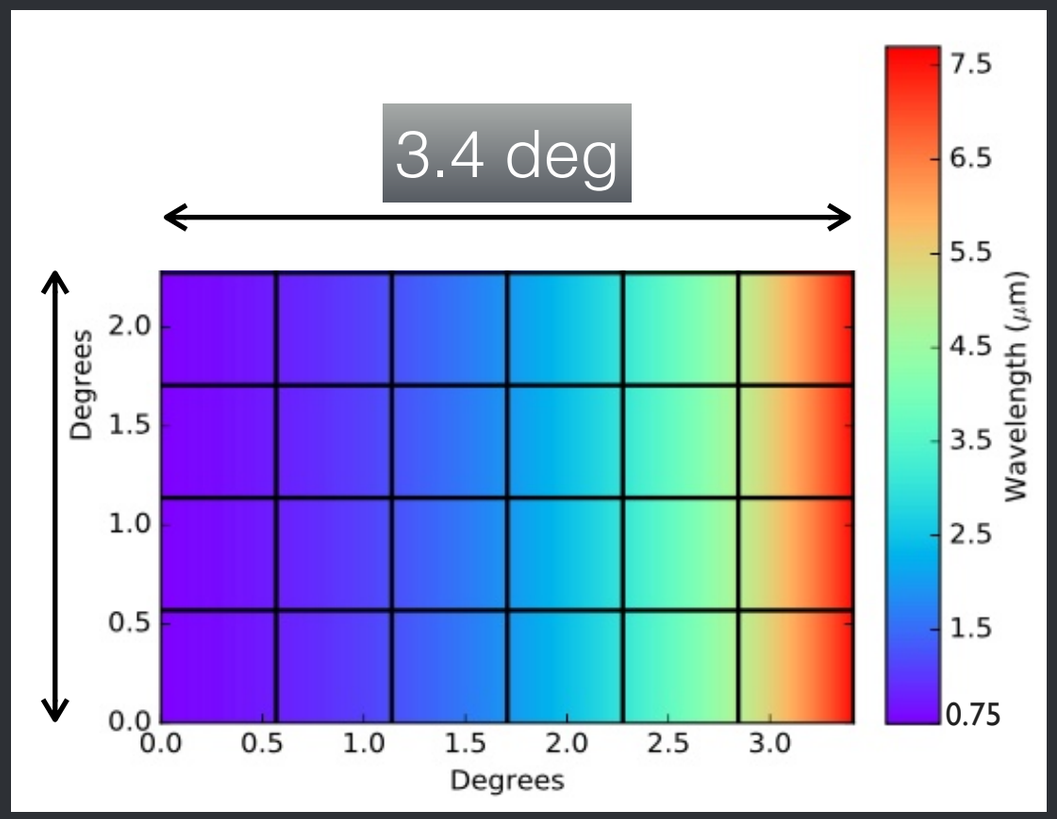
Linear Variable Filters (LVF) at R=300, 4x6 H2RG detectors

V-groove radiators, passive cooling at T<35K in L2 halo orbit

Ka-band HGA. Data rate ~400 Gbit/day, 1hr/day downlink

Design team & Team-X

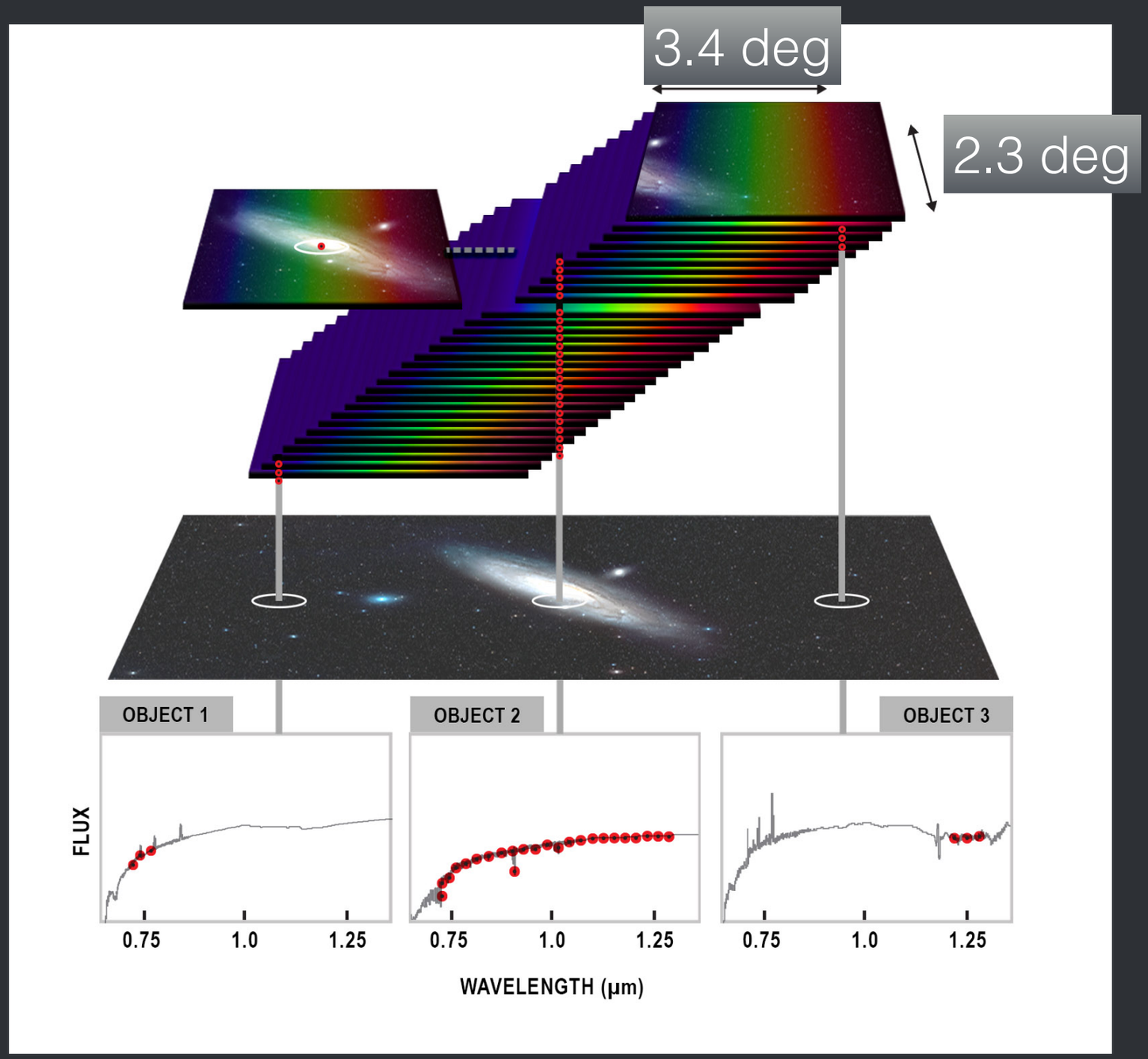
H2RG detectors, Linear Variable Filters (LVF) and the FoV



Design team

- HyViSi and H2RGs in 4x6 array across 0.75-7.5 microns; at R=300 resulting in 840 wavelength channels.
- 2.3 x 3.4 = 7.7 deg^2 FoV

Spectroscopy with Linear Variable Filters



Construct 3D spectral-imaging data cube at 1" pixels in 840 wavelength bands between 0.75 μm – 7.5 μm

- Build up wavelength coverage by stepping spatially, each step is 15"

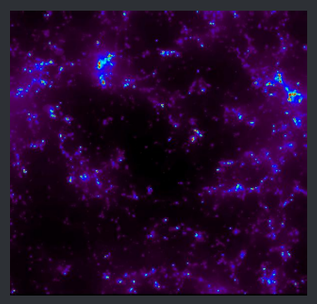
- Each exposure/step is 250s (ZL-limited), 5 days to build up a FoV-worth of full data cube

SPHEREx

CDIM Three-tiered Survey

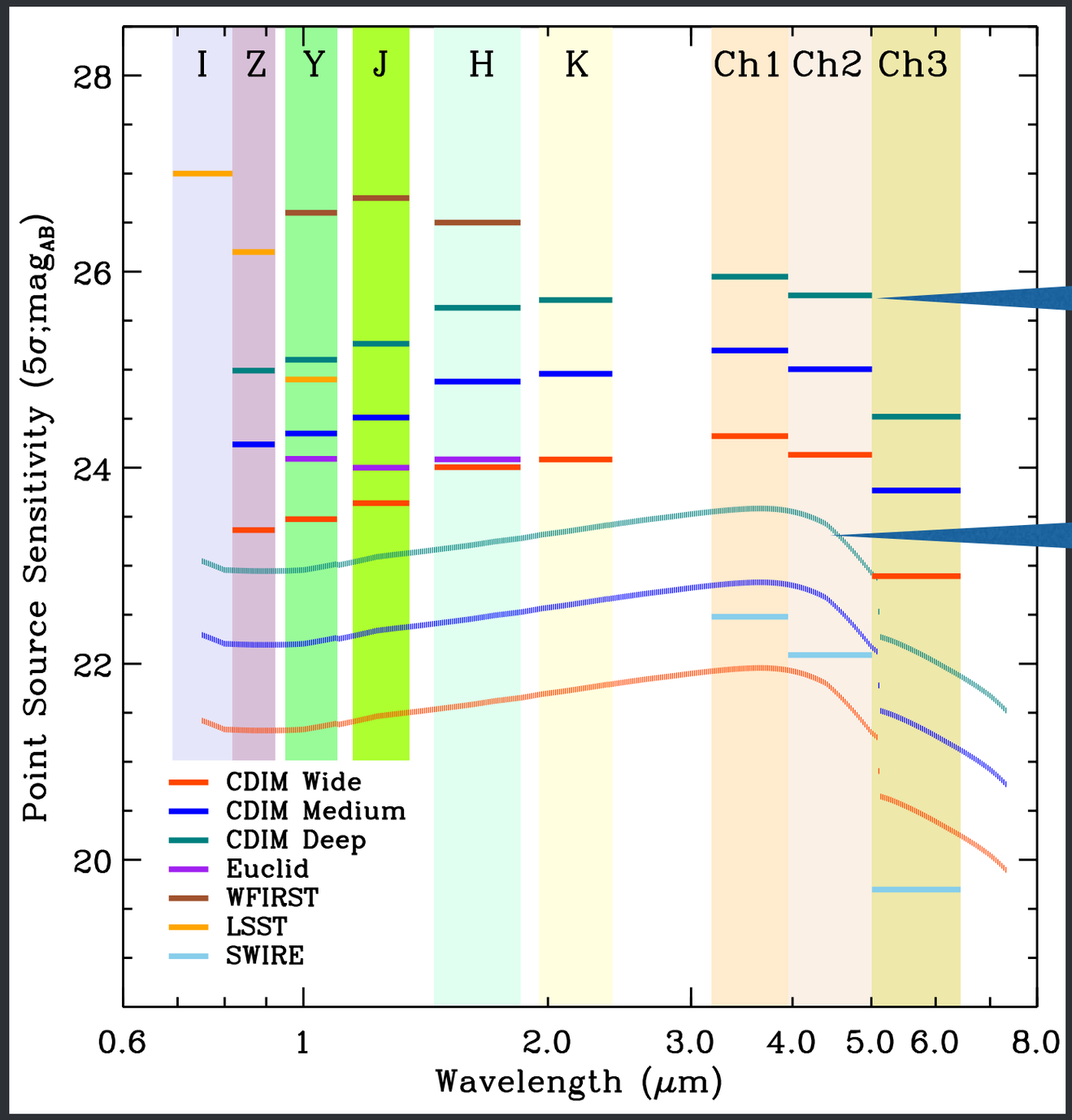
- Detecting faint, high-redshift galaxies
  - Deep survey; 15 deg^2 to overlap with WFIRST/Euclid deep fields
- Detecting bright, rare AGNs
  - Wide survey; 300 deg^2 to catch z=8 AGNs.

  - At either SEP or NEP, visible all-year round from L2, surrounding the Deep survey field



- Reionization tomography in synergy with 21cm intensity maps
  - Medium survey; 30 deg^2 to match a SKA 21cm EoR deep field likely overlapping with the ECDF-S and HERA
- Four years of survey

CDIM Point-Source Sensitivity

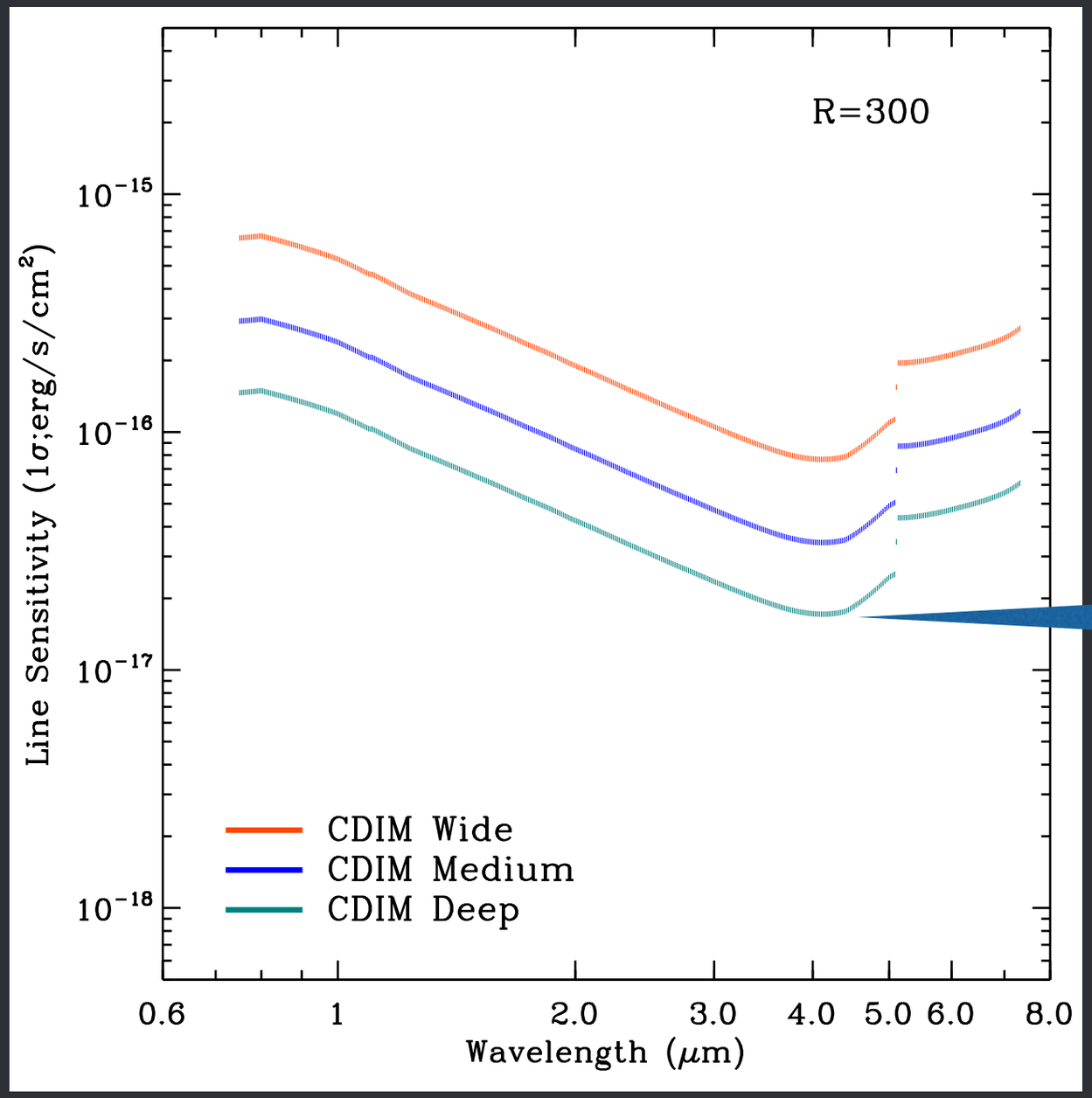


CDIM R=3
broad band

CDIM R=300
840 bands

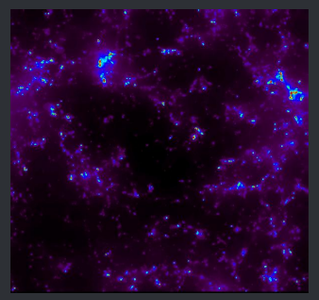
Hooshang Nayyeri & Michael Zemcov

CDIM Line-flux Sensitivity

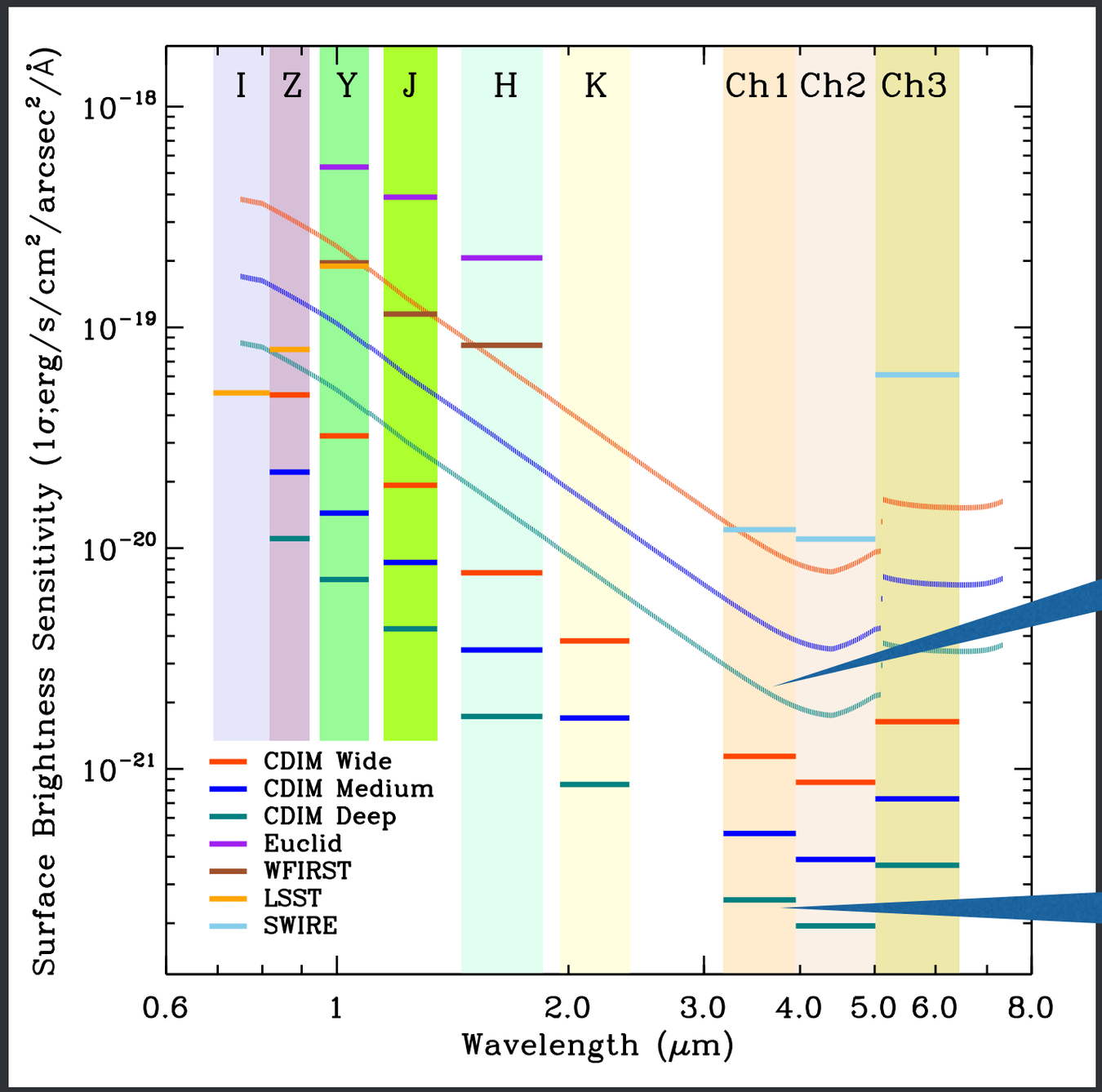


CDIM R=300
840 bands

Hooshang Nayyeri & Michael Zemcov



CDIM Surface Brightness Sensitivity



CDIM R=300
840 bands

CDIM R=3
broad band

Hooshang Nayyeri & Michael Zemcov

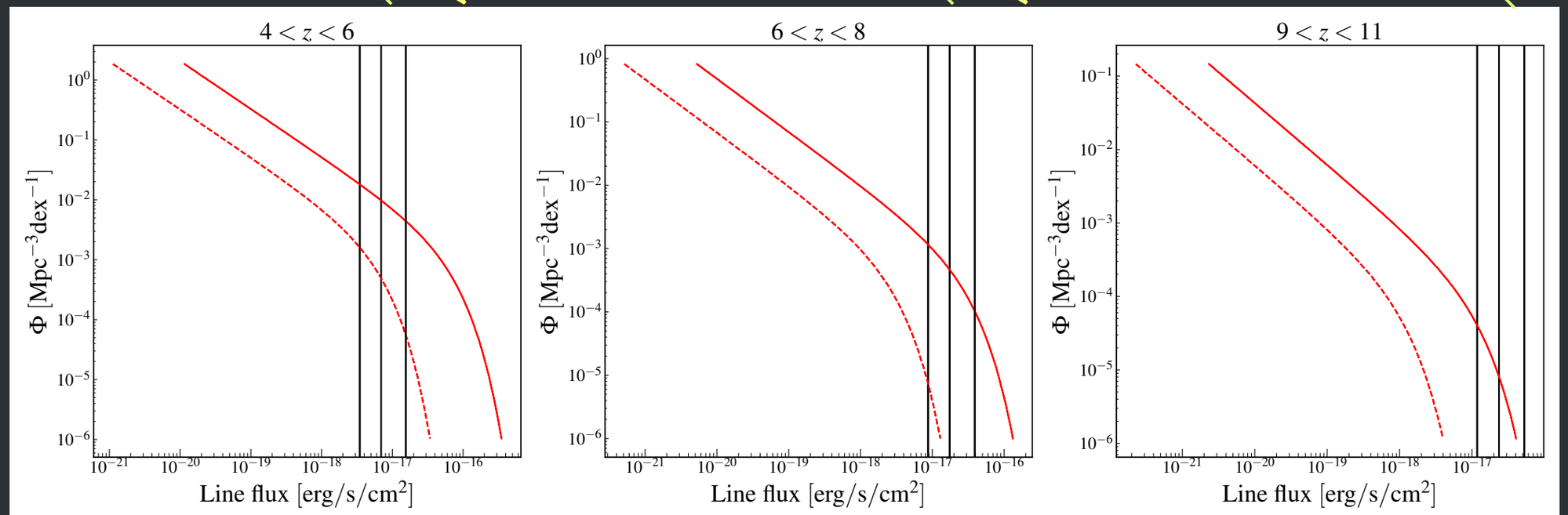
CDIM Traces Hα up to z ~10

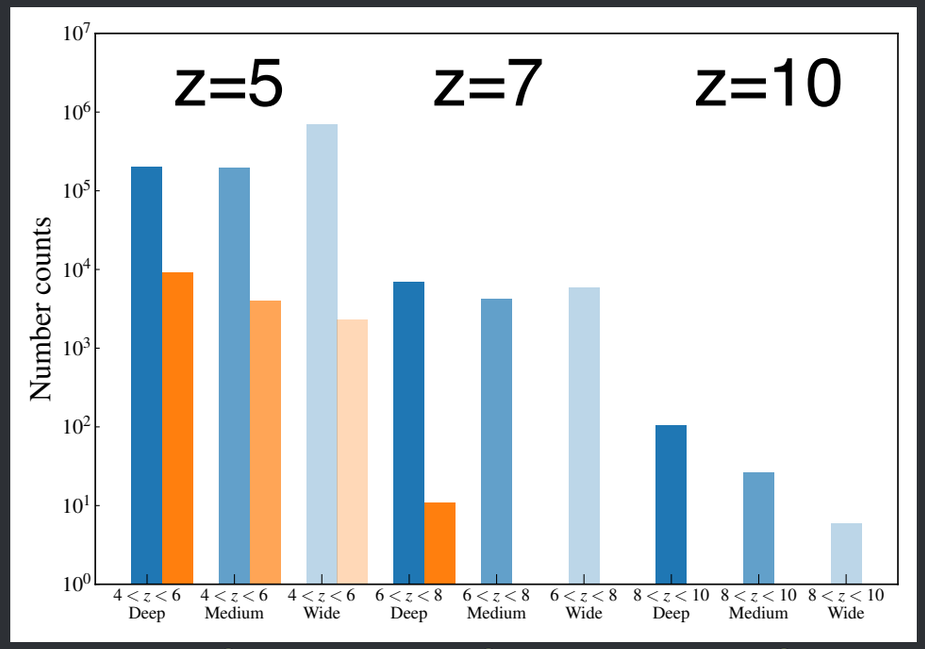
Preliminary!

deep Medium Wide

deep Medium Wide

deep Medium Wide





deep Medium Wide

deep Medium Wide

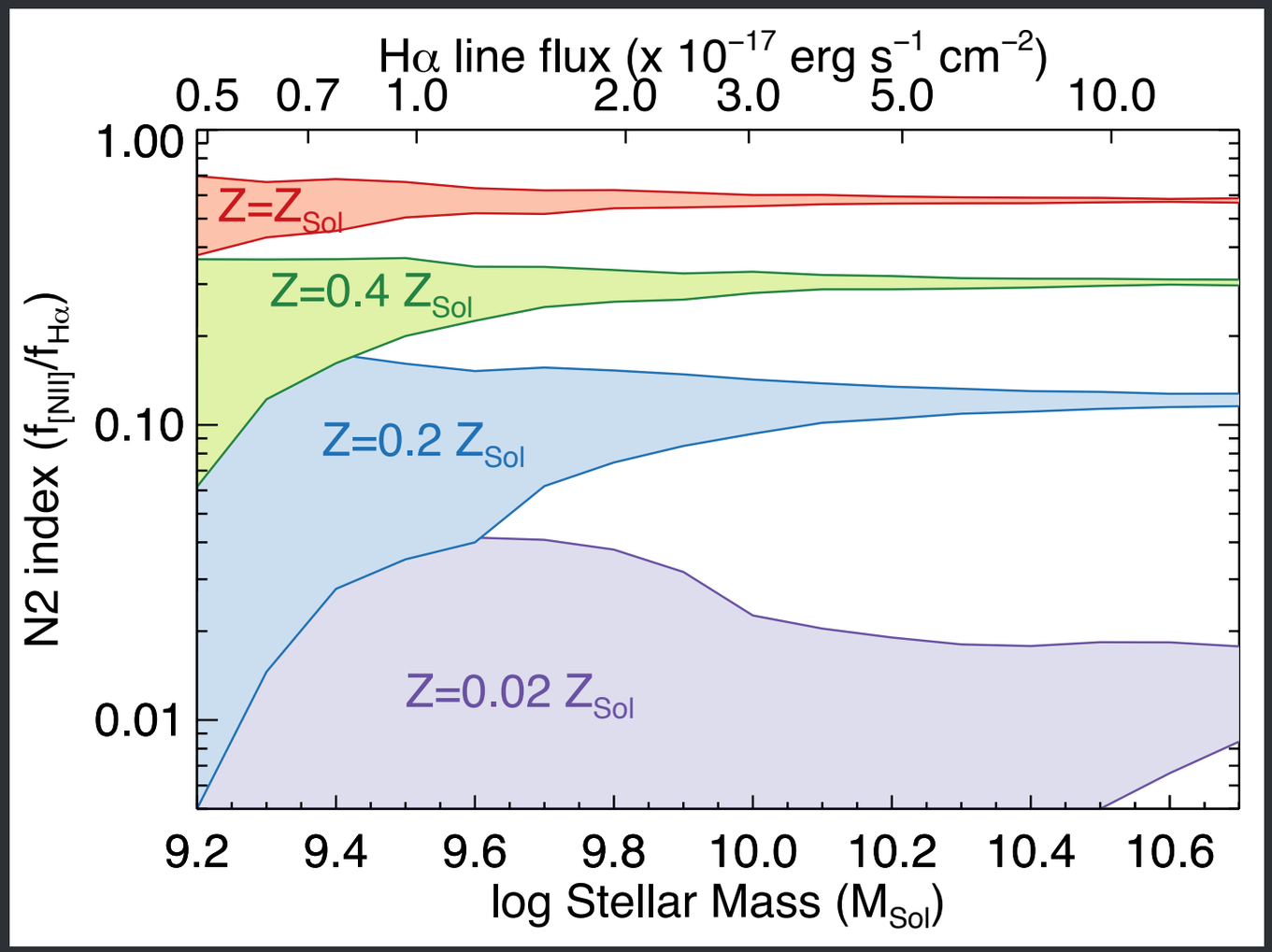
deep Medium Wide

Heidi Hao-Yi Wu

- Optimistic and pessimistic Hα luminosity functions based on Flexible Stellar Population Synthesis code (Conroy 2010), Millennium simulation, UV galaxy measurements and semi-analytic models
- Optimistic scenario leads to Hα detections up to z=10

Measuring Stellar Mass and Metal production

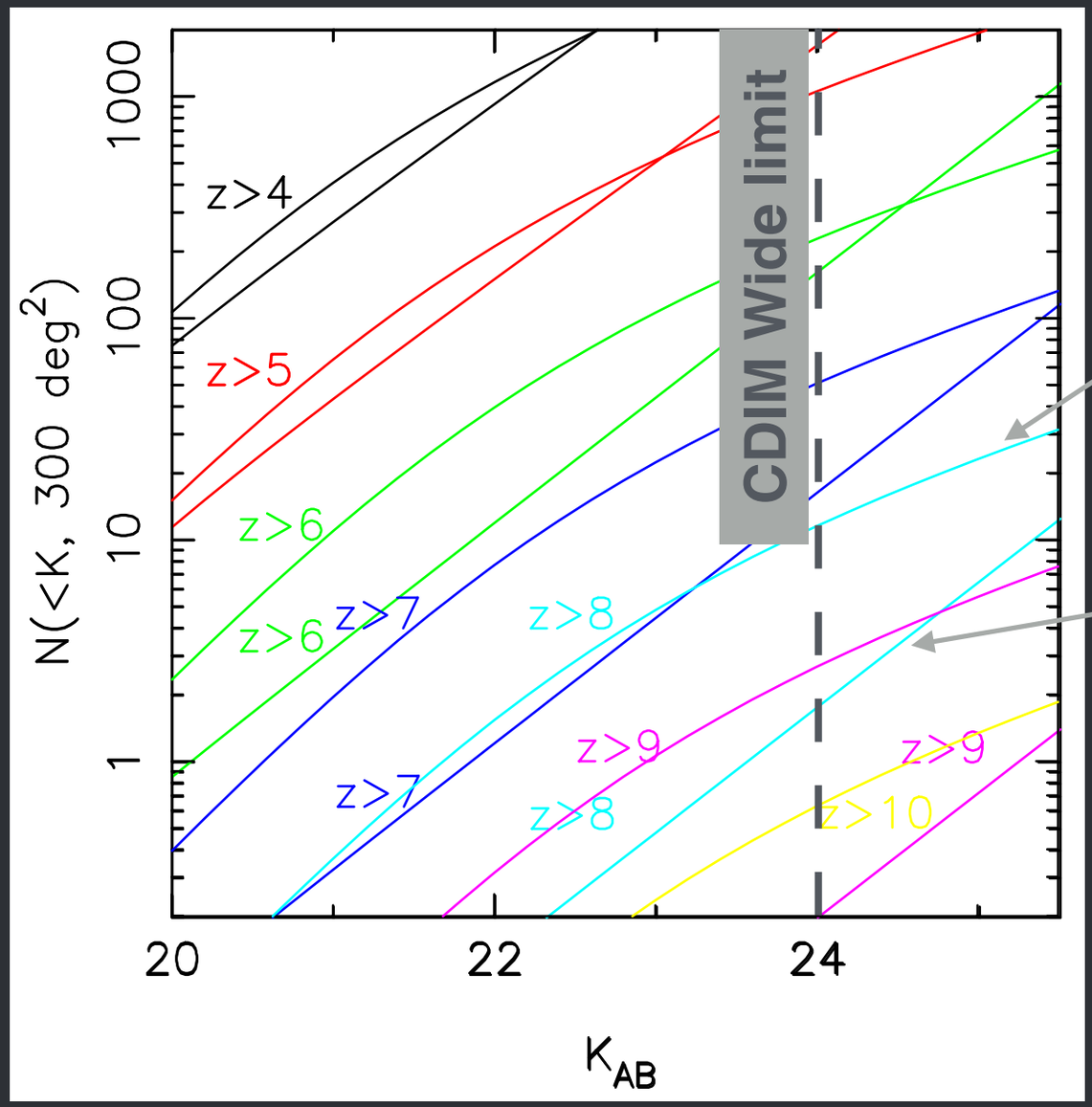
z=6



Steve Finkelstein

- Infer SFR from rest-frame UV and metallicity from [NII]/Hα.
- Trace stellar mass and metal build up across redshift

Finding AGNs out to z~8



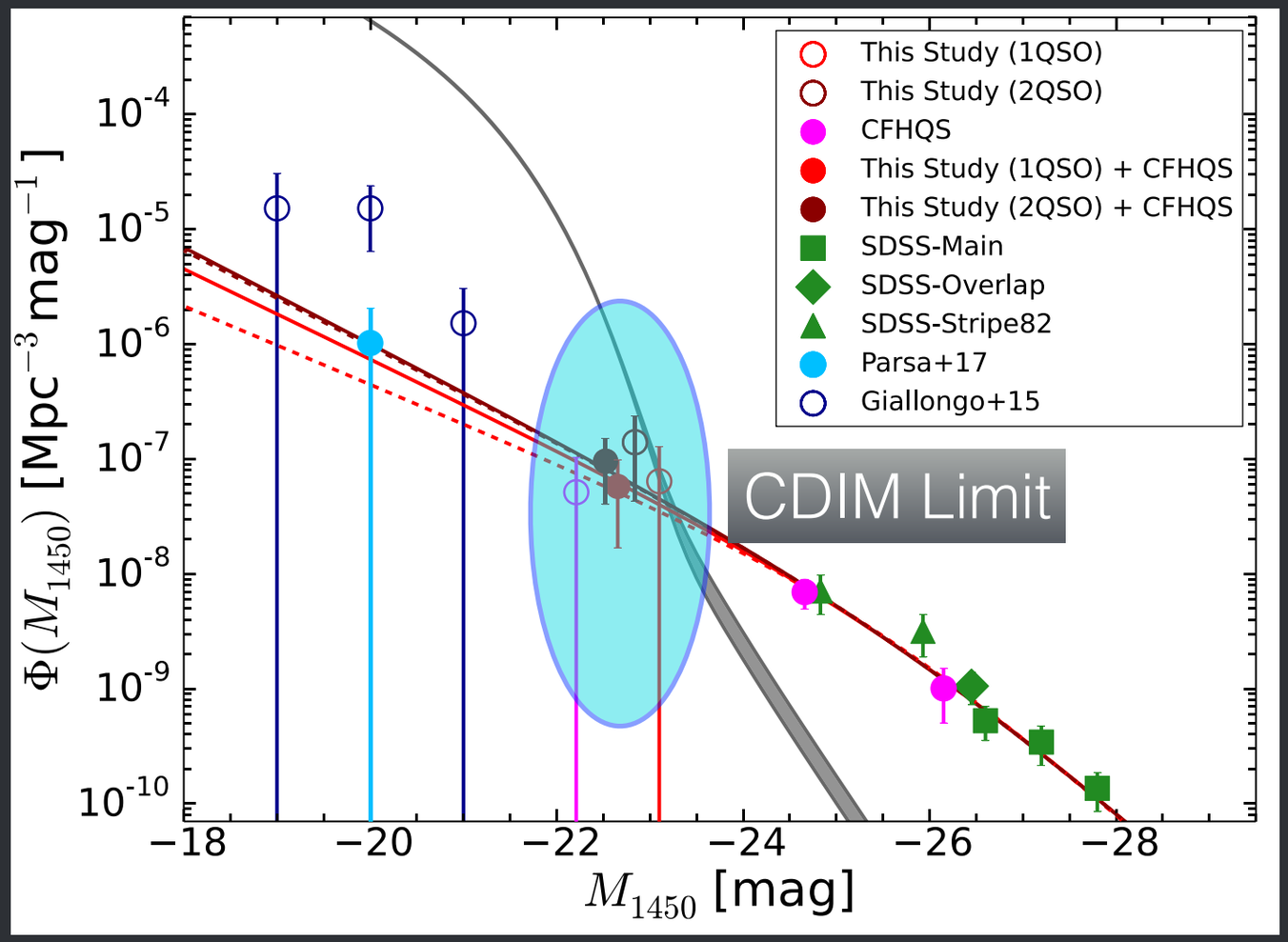
Willott+15 LF

Kulkarni+18, Wang+18 LF;
steeper faint-end slope

Xiaohui Fan

- Two quasar luminosity functions: based on Willott+15 and Kulkarni+18 and Wang+18, which has a steeper faint-end slope
- Possibly finding >10 quasars at z=7 in CDIM Wide Survey

Estimating Blackhole Masses



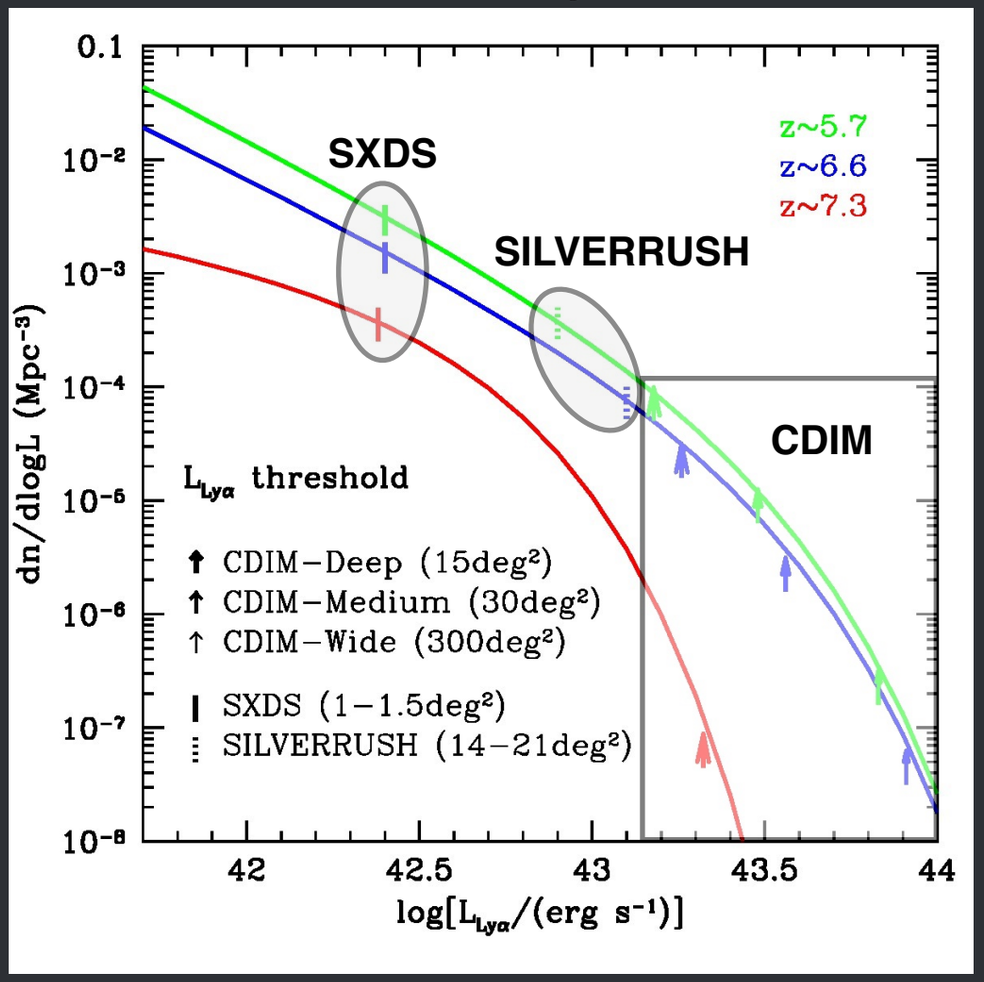
Onoue+18

Renyue Cen

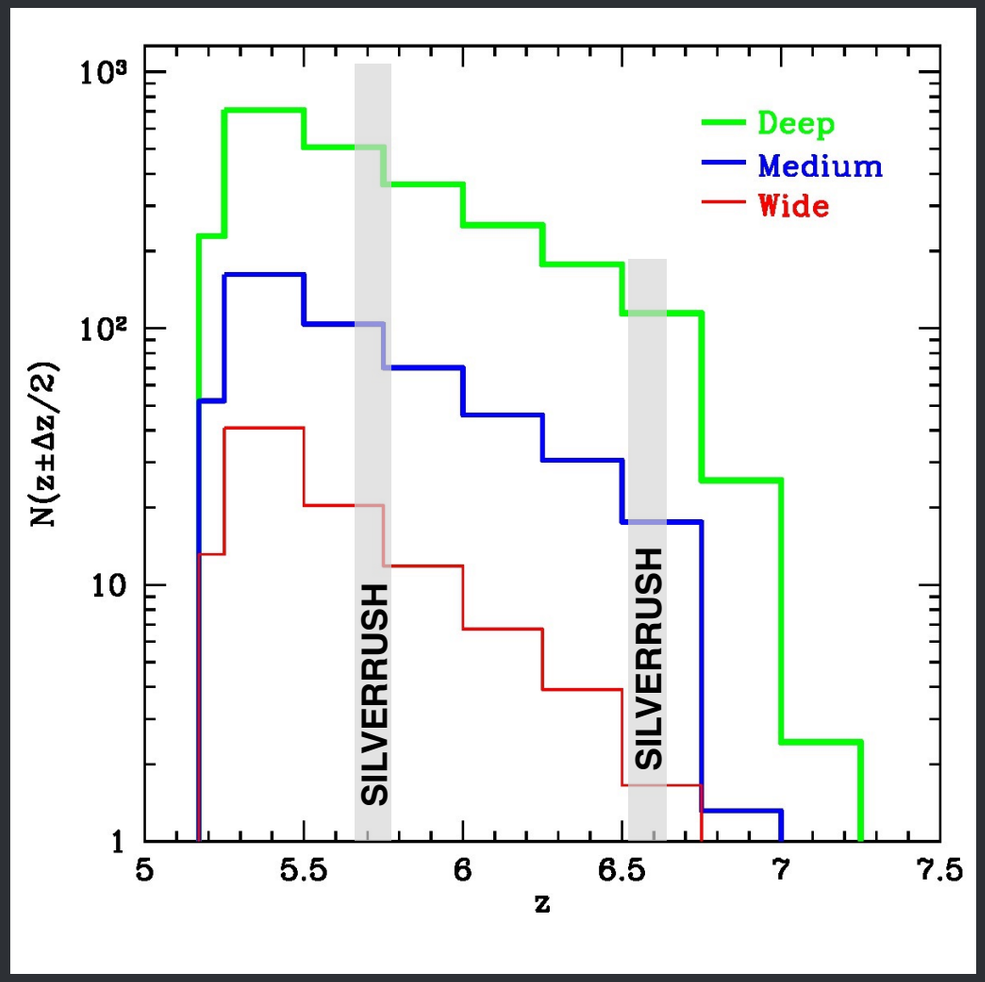
- CDIM will find ~100 quasars at z=6. Detection limit corresponds to a blackhole mass estimate of 10^7 M_{sun}, assuming Eddington accretion.

Detecting Lyα Emitting Galaxies

LAE luminosity function



LAE number count

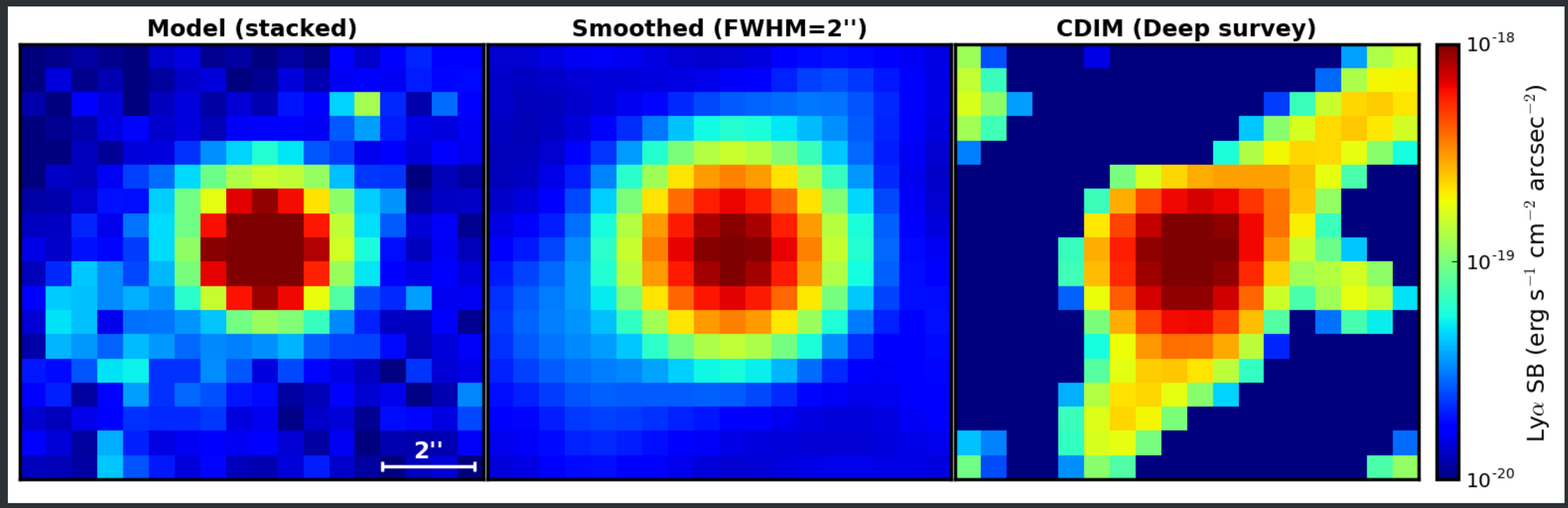


Zheng Zheng

- Detect a few thousand LAEs with $L_{Ly\alpha} > 10^{43}$ erg/s
- Determine the bright end of Lyα luminosity function at 5.2 < z < 7
- Hα counter part detectable out to z~9, can stack on Hα for fainter LAEs.
- CDIM spectral resolution ~ 6 Mpc/h at z=6 v.s. Silverrush narrowband at ~30 Mpc/h
- Constrain the evolution of ionization state of IGM

Fainter Lyα Emitters

Stacking Lyα images around Hα selected galaxies with CDIM



Raphael Sadoun

- Stacked LAE images using (83) CDIM detected Hα galaxies at z=5.7 within a 50^3 Mpc/h simulation volume
- Lyα images predicted by Lyα ray-tracing model + reionization simulations

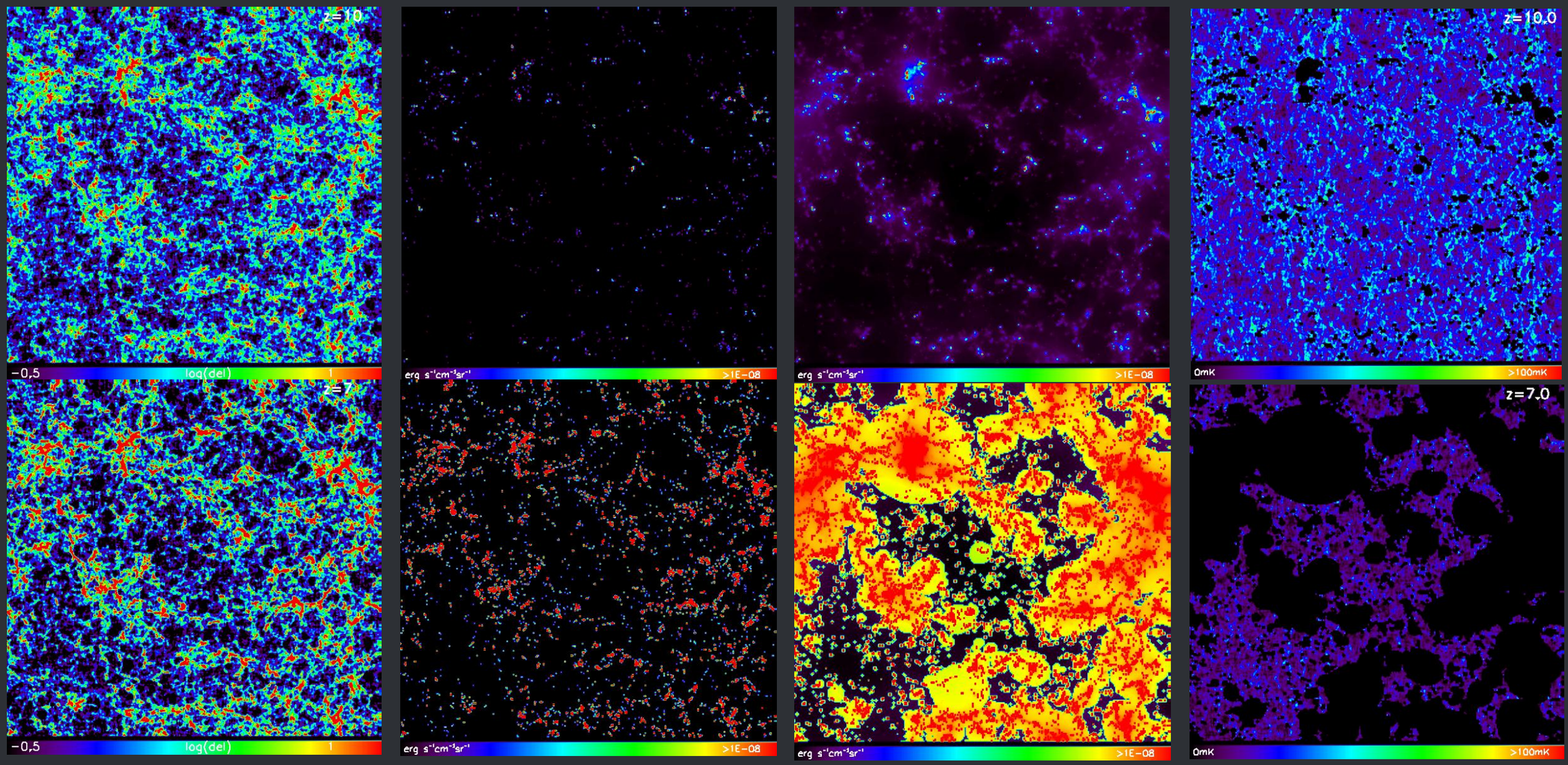
21cm, Hα, Lyα Reionization Tomography

Density fluctuation

Ionizing sources (traced by galactic Hα)

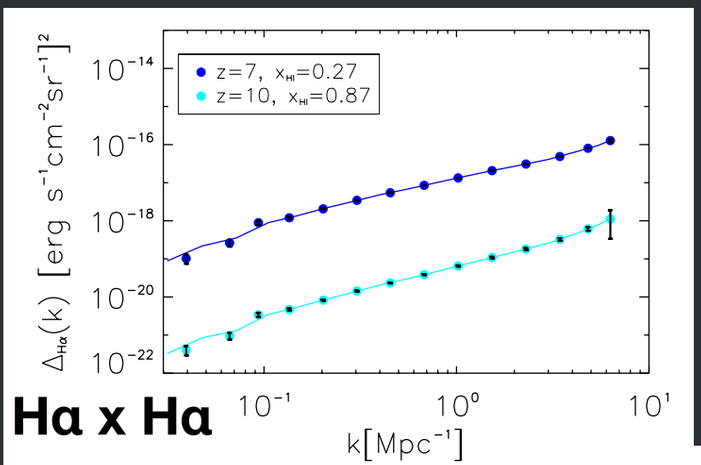
Partially ionized IGM (traced by scattering Lyα)

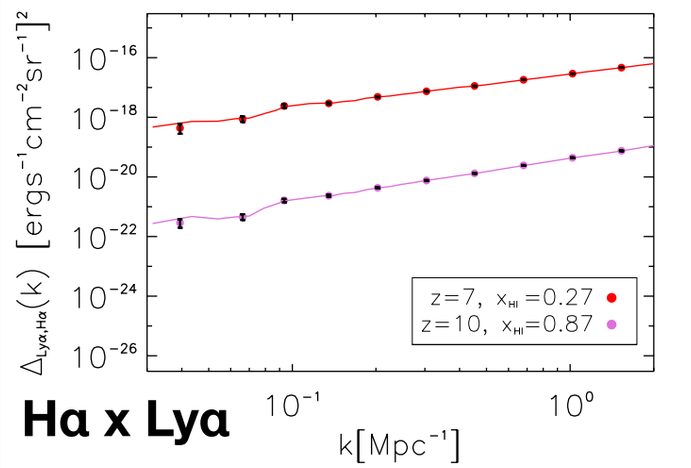
Neutral IGM (traced by 21cm)

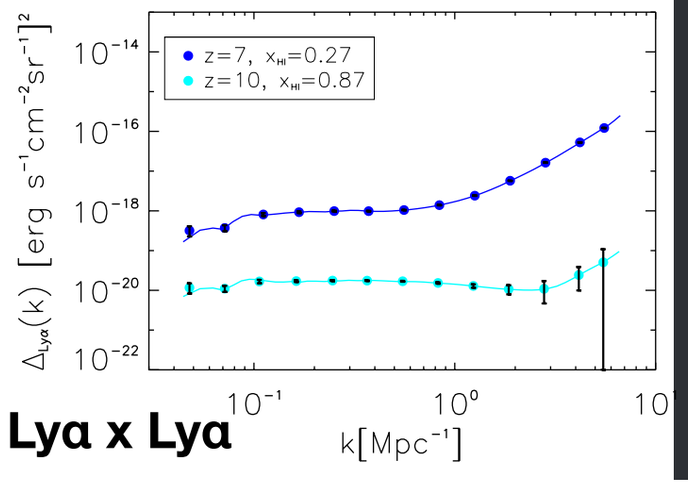


Caroline Heneka

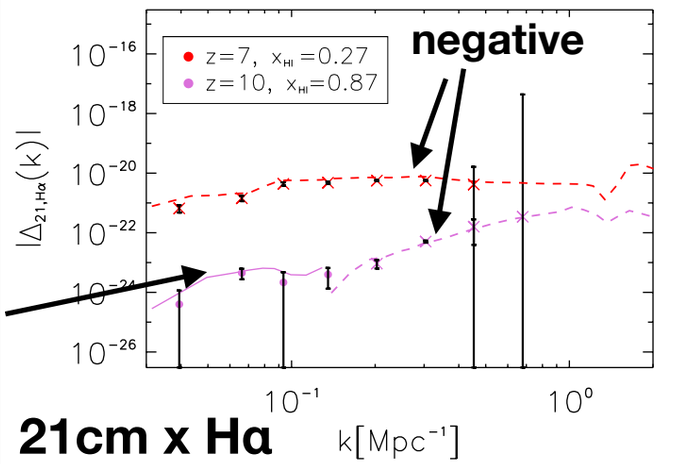
21cm, Hα, Lyα auto and cross-power spectra

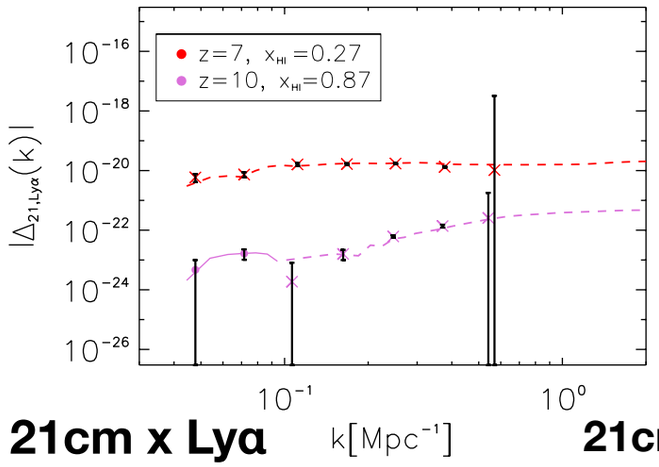


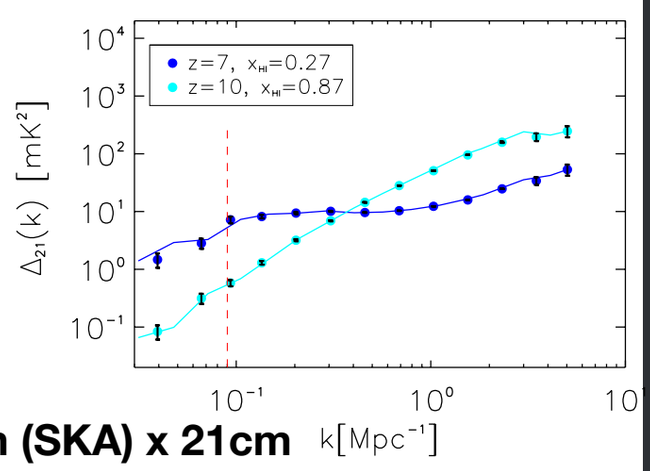




- Hα (and Lyα) trace ionizing sources. Lyα scatter in the ionized IGM. Cross-correlation can probe the scales of Lyα photon scattering in the IGM during EoR.
- 21cm x Hα and 21cm x Lyα are anti-correlated on typical scale of ionized regions. Can be used to trace bubble growth as a function of redshift.
- Cross-correlations are more robust against potential systematics. Verify 21cm cosmological signals.

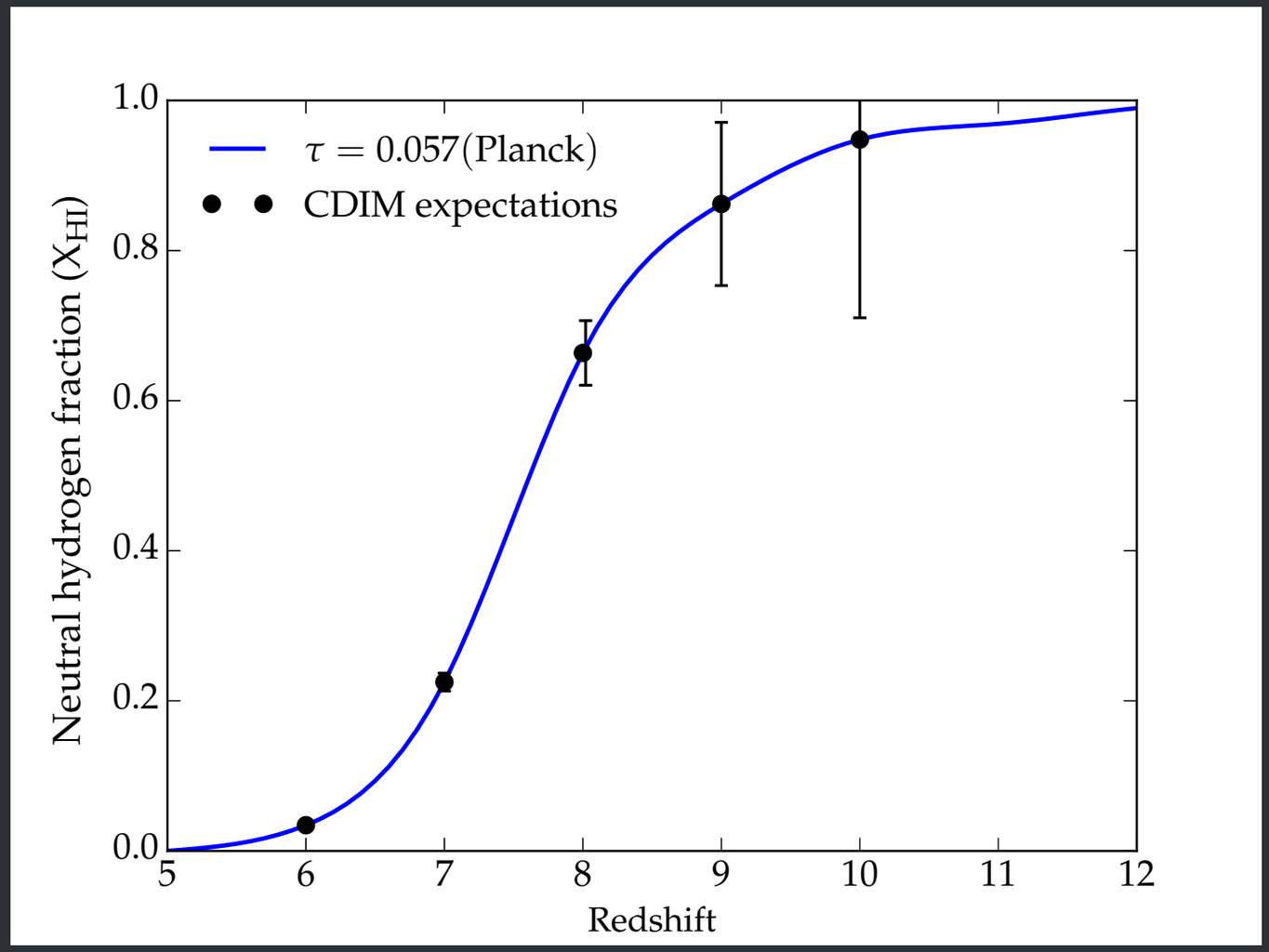


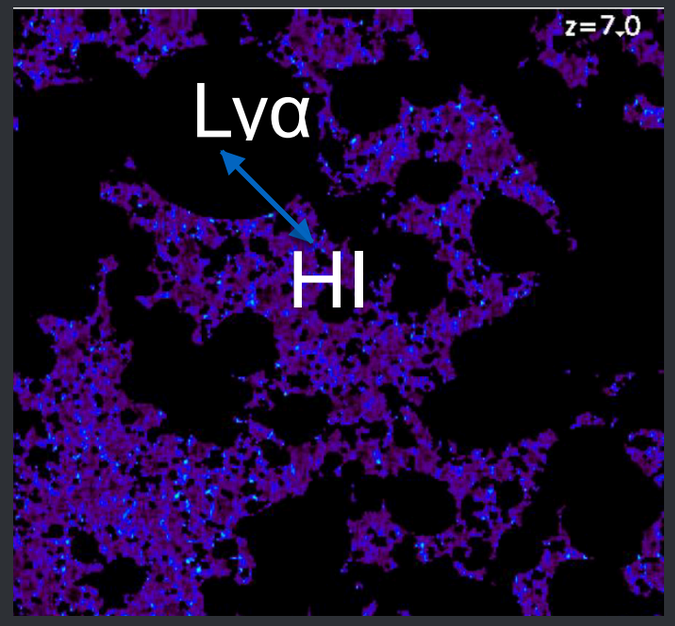




Caroline Heneka

Measuring Reionization History with CDIM





200 Mpc

Marta Silva

- Ionization fraction can be inferred from multiple measurements: evolution of LAEs, Hα and Lyα intensity evolution, and amplitudes of (21cm x Lyα) cross-power spectra.

Summary

- CDIM probe design developed:
  - 0.75 μm – 7.5 μm spectro-imaging at R=300
  - 0.8 m effective aperture, 1” pixel, 2” PSF
  - 7.7 sq. degree focal plane
  - Three-tired survey in 4 years (15, 30, 300 sq. degree)
  - Costed with Class-B margin

- Designed to probe Cosmic Dawn and Reionization in novel and powerful ways:
  - First Galaxies: tracing Hα to z=10, studying stellar mass and metal build up
  - First Blackholes: finding AGNs at z=8, constraining blackhole mass growth
  - Reionization Tomography: Lyα, Hα Intensity Mapping, cross-correlation with 21cm, to measure bubble growth and reionization history

- CDIM will deliver a unique data set and offer a holistic view of Cosmic Dawn and Reionization